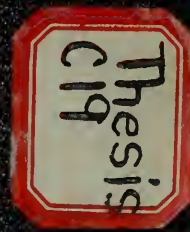


AN INVESTIGATION OF THE EFFECTS OF AN
ASPHALTIC EMULSION AS AN
ADMIXTURE ON THE PROPERTIES OF
PORTLAND CEMENT CONCRETE

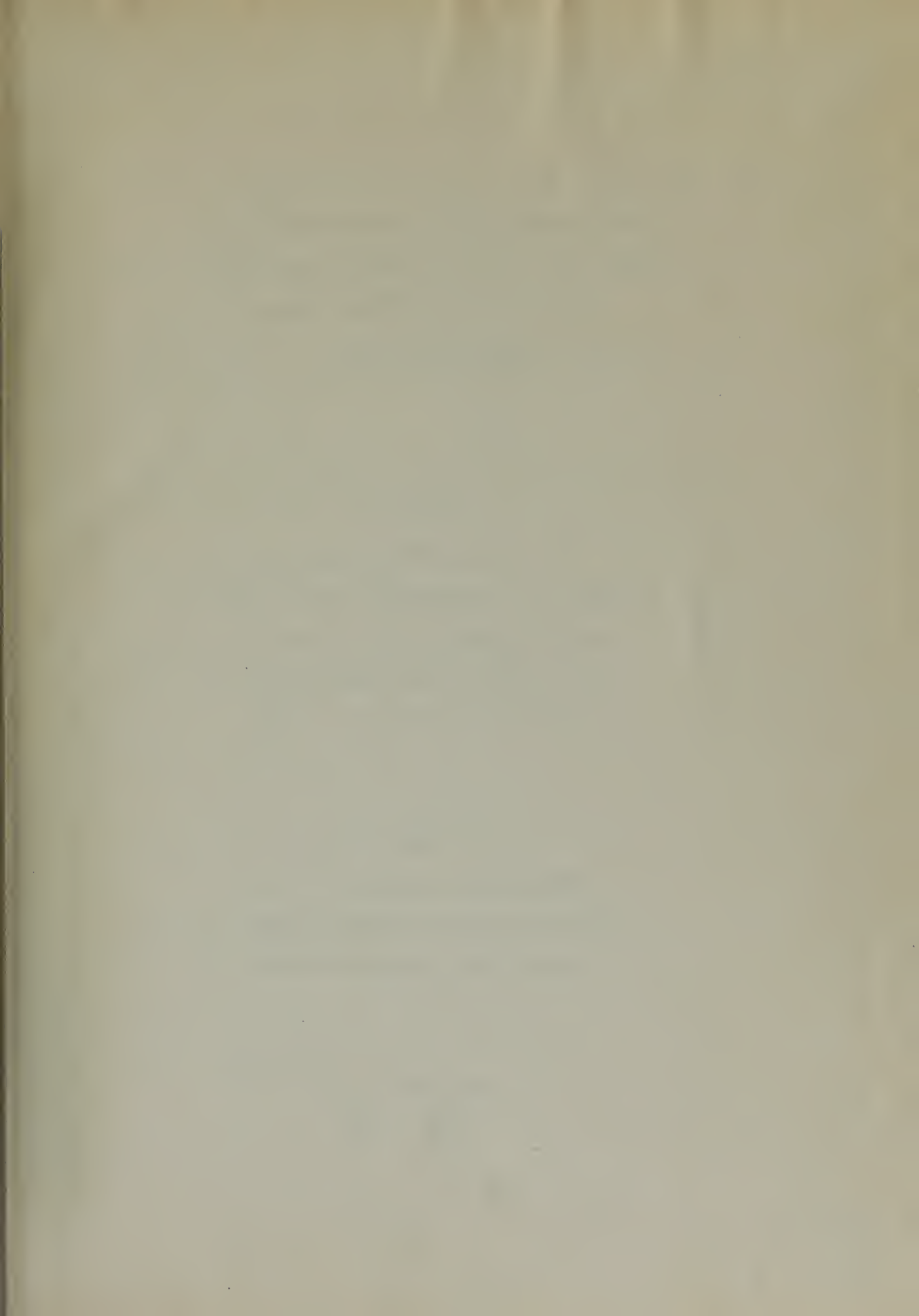
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AN INVESTIGATION OF THE EFFECTS OF
AN ASPHALTIC EMULSION AS AN ADMIXTURE
ON THE PROPERTIES OF PORTLAND
CEMENT CONCRETE

A thesis
presented to the faculty of
Rensselaer Polytechnic Institute
in partial fulfillment of the
requirements for the degree of
Master of Civil Engineering

by
John F. Callahan, Lt.(CEC)USN
John G. Hammer, Lt.(jg)(CEC)USN
Frank C. Hansche, Lt.(CEC)USN

Troy, New York

June, 1948

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Thesis
C19

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INTRODUCTION

Concrete construction has assumed a major position in modern civil engineering design. Because of its flexibility of use, architectural values, and general availability concrete is used even in instances where it might be inferior in some respects to other materials and methods of construction. Consequently, the general subject of improving concrete mixtures has been given considerable attention.

The idea of experimenting with bituminous admixtures in concrete is not original with the authors. Previous investigators have made thorough studies of such mixtures as a means of physically waterproofing concrete by the dispersion of the bituminous product throughout the pores of the concrete. Such was the work of Mr. Sanborn and Mr. Taylor, conducted in 1913. Their tests showed reduced permeability with an attendant reduction of strength. Mr. Taylor and Mr. Sanborn used a series of bituminous oils in varying quantities and confined their experiments to one general classification of oils.

In Germany prior to the second World War, considerable work was done on the use of bituminous products in concrete for highway work. German engineers were concerned with the effects of repetitive freezing and thawing on concrete and its strength. References to this work are appended below.

This thesis attempts to expand on previous work and to make a study with perhaps an entirely new object. Full credit

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should be given to Mr. H. J. Grathwol of Silver Spring, Maryland, for his original idea of using an asphalt emulsion as an admixture for the purpose of controlling temperature stresses in concrete. Mr. Grathwol, after his theoretical considerations, contacted Professor H. O. Sharp, of Rensselaer Polytechnic Institute, and the subject was deemed worthy of presentation for a master's thesis.

Complete results cannot be achieved here, however. Time limitations have fixed the scope of the work. In investigating a subject as broad as the use of admixtures in concrete, various arbitrary choices have to be made in order to reduce the variables. In the types and kinds of asphaltic emulsions alone there are far too many to give consideration to each. In the kinds of aggregate the situation is no better. Moreover, some of the important tests, notably expansion, could not be performed because they required six months or more for completion. As a result certain tests were selected using known standards and correlating the results on a comparative basis.

After a study of available research material in the Rensselaer Polytechnic Institute library and the Engineering Societies Library in New York City, the writers confined the scope of the investigation to work which it is hoped will add to the present knowledge of asphaltic emulsion as an admixture. The objectives are: to study the reaction between a bituminous emulsion and concrete mixtures by testing the physical properties of the resulting concrete; to determine the percentages

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The limitations have been the scope of the work. In investigating a subject as broad as the use of admixtures in concrete, various arbitrary choices have to be made in order to reduce the material. In the types and kinds of asphaltic emulsions alone there are too many to give a complete list. In the study of asphalt the following is no doubt. However, some of the most important, notably expansion, could not be mentioned because they required six months of work for completion. As a result certain facts were selected which show the limitations and correlating the results on a comparative basis.

After a study of available research material in the American Polytechnic Institute Library and the Engineering Research Library in New York City, the writer outlined the scope of the investigation as work which is being left to the present knowledge of asphaltic emulsion as an admixture. The objectives were to study the reaction between a cementitious material and concrete admixture by testing the physical properties of the resulting concrete to determine the advantages

of emulsion producing the most desirable properties; to study the disperse phase of the asphalt particles; to study air entrainment.

The experimental work consists of a series of tests applied to specimens of varying composition, age, and treatment. Different methods of handling the asphalt emulsion, mixing the concrete, and obtaining consistencies were tried, as is explained below. Whenever possible the procedures recommended by the American Society for Testing Materials were followed. Whenever this was not the case, the reasons for and description of the procedure used are given.

As stated before, the work presented here is necessarily that done in one school semester. The results cannot be complete, but they are intended to be a contribution to a very important phase of the profession of Civil Engineering.

of condition producing the most desirable properties; to study the changes made at the various periods; to study the treatment.

The experimental work consists of a series of tests applied to specimens of varying composition, age, and treatment. Different methods of treating the material, mixing the concrete, and obtaining consistent results were tried, as is explained below. Whenever possible the procedure recommended by the American Society for Testing Materials was followed. Whenever this was not the case, the reasons for and description of the procedure used are given.

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PHASE I
METHOD FOR DETERMINING OPTIMUM
ASPHALTIC EMULSION CONTENT

The first test that was made was to determine the amount of asphalt emulsion to be added to the concrete mix. This was done by testing the cement mortar, using as a maximum the quantity of emulsion, expressed as a percent by weight of Portland Cement, until the strength of the specimen was approximately equal to the strength of a 1:3 mortar mix without the admixture of emulsion. It was decided to do this by following the Standard Method of Sampling and Physical Testing of Portland Cement ASTM Designation C 77-40. In this test a quantity of the cement to be used throughout the laboratory work was first sieved through a number 20 sieve. Standard Portland Cement estimated to be about six months old was used. Three series of briquets were made, one with standard Ottawa sand, the second with a sample of the sand to be used for all the tests which was Cow Bay sand with a sieve analysis as given elsewhere in this report. The third series of briquets was made up of cement mortar briquets with percentages of asphalt as follows: One, Two, Three, Four, Six, Eight, Ten, Twelve percent of emulsion. The large range was required since nothing was known of the quantity of emulsion required to give a strength approximately equal to the standard 1:3 mortar mix.

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In mixing the Ottawa sand and Cow Bay sand standard briquets, it was first necessary to determine the normal consistency of neat cement. Normal consistency of neat cement is the amount of water required to cause a settlement of the rod of a Vicat apparatus to a point ten millimeters below the original surface in thirty seconds after being released, following the standard procedure for mixing the samples. Several trial mixes were made until the cement was determined to have a normal consistency with thirty percent water. From the table of percentage of water for neat cement paste of normal consistency against percentage of water for mortar of one cement to three standard sand it was found that eleven and one-half percent was required for the standard briquets. At this point it was necessary to decide whether to use an amount of water equal to eleven and one-half percent of the weight of sand and cement and add the emulsion without accounting for the water in the emulsion or to subtract the amount of water in the asphalt and use an additional amount of water to make up the eleven and one-half percent required. The latter was the method followed using an emulsion composed of sixty percent asphalt and forty percent water. Since the briquet moulds were gang moulds each containing three moulds and three samples each of Ottawa sand standard specimens, Cow Bay sand specimens and each percentage of asphalt emulsion, the following amounts of sand, cement and water were used for each batch cast:

In making the Ottawa sand and Cow Bay sand specimens, it was first necessary to determine the normal consistency of each cement in the amount of water required to cause a set of the top of a 100 g. test specimen to a point 25 mm. below the original surface in thirty seconds after setting. Following the standard procedure for making the samples, several trial mixes were made until the cement was determined to have a normal consistency with thirty percent water. From the table of percentages of water for next normal basis of normal consistency against percentage of water for mortar of one cement to three standards sand it was found that eleven and one-half percent was required for the standard specimen. At this point it was necessary to decide whether to use an amount of water equal to eleven and one-half percent of the weight of sand and cement and add the surplus without accounting for the water in the solution or to subtract the amount of water in the sample and use an additional amount of water to make up the eleven and one-half percent required. The latter was the method followed using an emulsion composed of sixty percent asphalt and thirty percent water. Since the proper emulsion was being made, the remaining three samples and three samples each of Ottawa sand standard specimens, Cow Bay sand specimens and each percentage of asphalt emulsion, the following amounts of sand, cement and water were used for each batch cast:

Sand - 450 grams

Cement - 150 grams

Water - 69 ml

The following table gives the amount of water for each percentage of asphalt used.

Asphalt Percent	1	2	3	4	6	8	10	12
Grams of Emulsion	6	12	18	24	36	48	60	72
Actual Asphalt	3.6	7.2	10.8	14.4	21.6	28.8	36.0	43.2
Actual Water	2.4	4.8	7.2	9.6	14.4	19.2	24.0	28.8
Required Water	66.6	64.2	61.8	59.4	54.6	49.8	45.0	40.2

The standard mortar was mixed following the ASTM procedure by mixing the sand and cement dry and then adding the water. Again there was no precedent to follow in adding the asphalt emulsion so that in the process of mixing the batches, several different methods were tried. First the water was added to the cement-sand mixture, then the asphalt emulsion was added and the mixture kneaded and placed in the mould. A second method tried was to add the emulsion to the dry sand and cement and then add the water. The third method tried was to mix the water and emulsion together in a separate container and then add it to the cement-sand mixture. The last mentioned was found to be most satisfactory although

Sand - 450 grams

Cement - 150 grams

Water - 55 ml

The following table gives the amount of water for each

percentage of asphalt used.

Asphalt Percent	1	2	3	4	5	6	7	8	9	10	11	12
Volume of Emulsion	6	12	18	24	30	36	42	48	54	60	66	72
Actual Asphalt	7.5	7.2	10.8	14.4	21.6	28.8	36.0	43.2	50.4	57.6	64.8	72.0
Actual Water	2.4	4.8	7.2	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2	48.0
Required Water	60.4	64.2	61.8	59.4	54.6	49.8	45.0	40.2	35.4	30.6	25.8	21.0

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method tried was to mix the water and emulsion together in a

separate container and then add it to the cement-sand mixture.

The last mentioned was found to be most satisfactory although

it was found difficult to achieve a thoroughly homogeneous mass and some evidence of lumps of asphalt in the mortar was discovered in the mixing process.

As each batch of mortar was mixed it was placed in the gang mould on unoled glass plates. The moulds were oiled with a thin film of mineral oil before being filled with the mortar paste. The moulds used were standard briquet moulds for tensile strength tests.

After moulding, all test specimens were immediately placed in a moist closet at a temperature of $21^{\circ} \pm 1.7^{\circ}$ centigrade and at a relative humidity of ninety percent. The specimens were left in the moulds and kept on plane glass plates for a period of twenty-four hours. At the end of this period the specimens were removed from the moist closet and from the moulds and placed under water for a period of six days so that the specimens were aged seven days at the time of testing. The specimens were tested as soon as they were removed from the storage water in a tensile testing machine with the load applied at the rate of six hundred pounds per minute. Briquets which gave strength differing by more than fifteen percent from the average value of all test specimens made from the same mixture were assumed to be faulty and were not considered in determining the tensile strength.

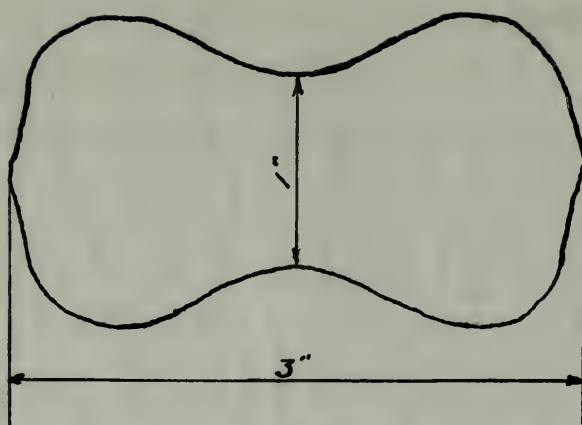
Since the briquets are of the dimensions as shown below, the tensile strength in pounds per square inch was the breaking load of the specimen.

it was found difficult to achieve a thoroughly homogeneous mass and some evidence of lumps of material in the water was discovered in the mixing process.

As each batch of material was added to the vessel in the same manner as the first batch, the moulds were filled with a thin film of mineral oil before being filled with the water paste. The moulds used were standard bridge moulds for tensile strength tests.

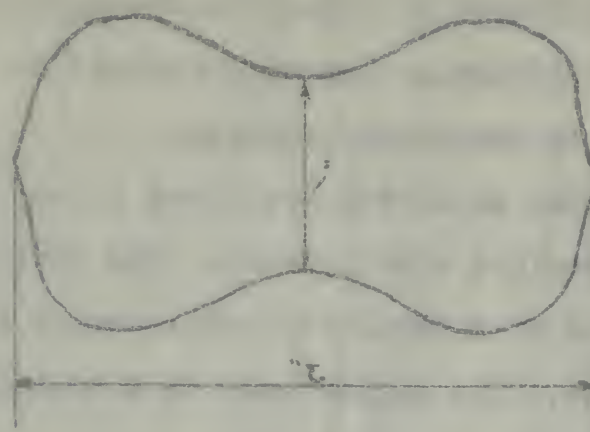
After moulding, all test specimens were immediately placed in a water bath at a temperature of $21 \pm 1.5^\circ$ centigrade and at a relative humidity of ninety percent. The specimens were left in the moulds and kept on glass plates for a period of twenty-four hours. At the end of this period the specimens were removed from the water bath and from the moulds and placed in water for a period of six days so that the specimens were aged seven days at the time of testing. The specimens were tested as soon as they were removed from the storage water in a tensile testing machine with the load applied at the rate of six hundred pounds per minute. Brackets which gave accurate dilation of more than fifteen percent from the average value of all test specimens were from the same moulds were assumed to be faulty and were not considered in determining the tensile strength.

Since the brackets are of the diamond shape as shown below, the tensile strength in pounds per square inch is the average load of the specimen.



The results of the tensile tests are shown in the graph following and it can be seen that the strength decreases as asphalt emulsion is added in larger amounts. Upon breaking the specimens in the tensile testing machine and examining the fracture, it was seen that in many cases the asphalt emulsion had not completely dispersed throughout the briquets leading to the conclusion that only a small percentage of emulsion could be used in mixing the concrete test specimens. Some concern was felt after discovering the segregation of the asphalt in the mortar briquets but from the known fact that the properties of the bituminous emulsion cause it to adhere to moist coarse aggregate, it was thought that this segregation would not be present when using the emulsion in a standard 1:2:3 concrete mix.

As the curve of tensile strength from this series of tests showed a continuous decrease with the addition of from



The compound specimens are shown in the graph following and it can be seen that the specimens are of various sizes and shapes. From observing the specimens in the female feeding machine and examining the tracings, it was seen that in many cases the female specimen had not completely digested through and the highest leading to the conclusion that only a small percentage of specimens could be used in making the concrete test specimens. From concrete test specimens also observing the suggestion of the female in the work of the female but from the above fact that the properties of the specimens would be so much as to make them unsuitable, it was thought that this suggestion would not be correct when using the specimen in a standard test. As the state of female strength from this series of tests showed a continuous decrease with the addition of time

zero to twelve percent emulsion it was decided to cast concrete specimens containing zero, one, two and three percent of asphalt emulsion by weight of sand, stone and cement.

and cement.

percent of asphalt emulsion by weight of sand, stone
concrete specimens containing zero, one, two and three
zero to twelve percent emulsion it was decided to test

ANALYSIS OF ASPHALT EMULSION USED

Item No.	70 B
Grade	B
Water Percent	45 -
Asphalt Percent	55 ±
Homogeneous	Yes
Specific Gravity @ 77 °F	1.00 ±
Ash Percent	2.0 -
Furol Vis. @ 77 °F	30-65
Miscibility	-
Settlement, five days	3.0 -
Stone Mixing	--
Setting	Yes
Cement Mixing	--
Screen Test Percent	0.1 -
Demulsibility N/10 Percent	--
Demulsibility N/50 Percent	60 ±

ANALYSIS OF ASPHALT EXTENSION TEST

Item No.	75 B
Grade	B
Water Percent	1.5 -
Asphalt Percent	55 ±
Homogeneous	Yes
Specific Gravity @ 77 °F	1.00 ±
Ash Percent	0.0 -
Porosity @ 77 °F	10-15
Stability	-
Settlement, Five Days	0.0 -
Stone Mixing	--
Setting	Yes
Cement Mixing	--
Spaced Test Percent	0.1 -
Densibility W/10 Percent	--
Densibility W/50 Percent	40 ±

PHASE II

PROCEDURE FOR MIXING, MOULDING,
AND TESTING CONCRETE SPECIMENS.

Since the tension tests performed on the briquets (see curve) clearly indicated that increased quantities of the emulsion decreased the strength properties of the mortar, it was initially assumed that the same results would hold true for a concrete mixture using both coarse and fine aggregate. However, it was hoped that with the addition of the coarse aggregate somewhat better results would be obtained, because of the known affinity of asphaltic emulsions for moist stone. This affinity was lacking when sand alone was used. Furthermore it was also hoped that the segregation of the asphalt might also be remedied due to this same affinity. Therefore, it was decided to mould test samples containing emulsion equivalent to one, two and three percent of the total weight of sand, stone and cement in the mix.

For test purposes, a series of standard six by twelve inch concrete cylinders and a similar series of concrete beams six by six by twenty-four inches were cast. These series consisted of groups of three samples containing no emulsion, three containing one percent, three with two percent and three with three percent, a total of twelve cylinders and twelve beams. Similar groups were cast and cured for a period of seven days, twenty-eight days and forty-five days. It would have been desirable to have a longer curing period for certain of the groups in order to determine the effects of age on the concrete, but due to time limitations it was

TABLE II

PROCESSES FOR MIXING, MOLDING,
AND TESTING CONCRETE SPECIMENS.

Since the tensile tests performed on the specimens (see Table I) clearly indicated that increased quantities of the emulsion decreased the strength properties of the concrete, it was initially assumed that the same results would hold true for a concrete mixture using both coarse and fine aggregate. However, it was hoped that with the addition of the coarse aggregate somewhat better results would be obtained, because of the known affinity of asphaltic emulsions for moist surfaces. This affinity was lacking when sand alone was used. Furthermore it was also hoped that the segregation of the asphalt might also be retarded due to this wet affinity. Therefore, it was decided to make test specimens containing emulsion equivalent to one, two and three percent of the total weight of sand, stone and cement in the mix.

For each mixture, a series of standard air dry twelve inch concrete cylinders and a similar series of concrete beams six by six by twenty-four inches were cast. These series consisted of groups of three specimens containing no emulsion, three containing one percent, three with two percent and three with three percent, a total of twelve cylinders and twelve beams. Similar groups were cast and cured for a period of seven days, twenty-eight days and forty-five days. It would have been desirable to have a longer curing period for certain of the groups in order to determine how different of age on the concrete, but due to time limitations it was

necessary to limit the longest curing period to the aforementioned forty-five days.

The best materials obtainable were used throughout the moulding of the specimens. The fine aggregate was Cow Bay sand from Port Jefferson, Long Island, an analysis of which is appended to this section. In choosing the coarse aggregate, it was felt that a desirable standardization of specimens would be obtained by using a one-size aggregate, even though this would mean a sacrifice of strength. A sacrifice of strength was inconsequential, however, because the results are comparative. Therefore, a clean, sharp, crushed limestone aggregate which passed through a one-half inch mesh screen and was retained on a three-eighths inch mesh screen was used. Portland cement, clean water and asphalt emulsion comprised the remaining materials. The emulsion was obtained from Mr. E. C. Ketchum of the Socony Vacuum Oil Co., Inc., Albany, New York, an analysis of which has been given under Phase I of this text.

Due to space limitations it was necessary to carry on the work of moulding and curing the specimens at the U. S. Naval Supply Depot, Scotia, New York. Fortunately a heated building was obtained as well as a seven cubic foot power mixer. The heated building meant the difference between carrying on this work and abandoning it because of the severe cold weather. The mixer facilitated the accurate and thorough mixing of large amounts of concrete.

necessary to limit the longest cutting period to two days-mentioned forty-five days.

The best materials obtainable were used throughout.

The building of the specimens. The first specimen was a box made from Port Jackson, Long Island, an analysis of which is appended to this section. In constructing the specimen, it was left with a desirable examination of specimens would be obtained by using a one-day specimen.

Even though this would mean a section of specimen. A number of attempts were made to obtain a section, but the results are unsatisfactory. Therefore, a claim, made,

crushed limestone aggregate which passed through a one-half inch mesh screen and was retained on a four-eighths inch mesh screen was used. Portland cement, clean water and

specimen analysis compared the remaining material. The specimen was obtained from Mr. J. C. Schuman of the Brooklyn Cement Co., Inc., Albany, New York, an analysis of which has been given under Phase I of this test.

Due to space limitations it was necessary to carry on the work of building and setting the specimens at the U. S. Naval Supply Depot, Annapolis, New York. Fortunately a limited quantity was obtained as well as a seven cubic foot power mixer. The limited quantity meant the difference between carrying on this work and abandoning it because of the severe cold weather. The mixer facilitated the accurate and thorough mixing of large amounts of concrete.

A 1:2:3 mix was used throughout and all quantity measurements were made to an accuracy of one ounce. Regarding the question of workability, a three-inch slump was used for each batch. This was obtained by using the minimum possible addition of water combined with asphalt emulsion. In this manner the water-cement ratio was kept a minimum with a consequent maintenance of maximum strength for each specimen group. By thus allowing for the "break down" of the emulsion, sufficient water of hydration was assured.

In all cases, an attempt was made to simulate probable field conditions as regards methods of mixing while at the same time devoting stringent attention to laboratory techniques and accuracy. The greatest difficulty in this respect was in the method of applying the asphaltic emulsion. As explained heretofore, during the moulding of the mortar briquets, many methods of adding the emulsion were used. The best of these resulted in vigorously stirring the emulsion into the water and adding the resulting solution to the sand and cement. Water at room temperature was successfully used in this case probably because of the small amounts of emulsion used. Yet, when the same method was attempted with the larger amounts required for a three cubic foot batch, the emulsion broke down and a large lump of asphalt immersed in water was the result. The reason for this action is not definitely known. However, it is the opinion of the authors that large amounts of the emulsion will not go into solution unless the water is heated. Another method, which proved successful, was to add

A 1:1 mix was used throughout and all quantities were measured by weight. In the case of the cement, the quantity of water was determined by using a three-inch slump cone. This was obtained by using the minimum possible addition of water combined with asphalt emulsion. In this manner the water-cement ratio was kept a minimum with a consequent maximum strength for each specimen made. By thus allowing for the "break down" of the emulsion, sufficient water of hydration was assured. In all cases, an attempt was made to simulate possible field conditions as regards methods of mixing while at the same time devoting sufficient attention to laboratory technique and accuracy. The greatest difficulty in this respect was in the method of applying the asphaltic emulsion. As explained previously, having the moulding of the mortar prepared, many methods of adding the emulsion were used. The best of these resulted in thoroughly stirring the emulsion into the water and adding the resulting solution to the sand and cement. Water at room temperature was successfully used in this case, probably because of the small amounts of emulsion used. Yet, when the same method was attempted with the larger amounts required for a three cubic foot batch, the emulsion broke down and a large lump of asphalt immersed in water was the result. The reason for this action is not definitely known. However, it is the opinion of the authors that large amounts of the emulsion will not go into solution unless the water is heated. Another method, which proved successful, was to add

the required amount of emulsion to the wet mix. Satisfactory distribution was thus obtained with no visible segregation in the wet concrete from the mixer. The resultant success in the use of this method is most probably due to the affinity of the emulsion for wet stone. This method was deemed more desirable than heating the water since it more nearly simulated the probable field method. It was hoped, at this point, that due to this same affinity, the segregation of the asphalt, as noted in the mortar briquets, would not occur in the concrete. A further discussion of the possibilities of adding asphaltic admixtures is included in the conclusions to this thesis.

In moulding the concrete beams, wooden forms were used, whereas for the cylinders standard six inch by twelve inch steel moulds were used as well as six by twelve inch cardboard cylinders procured from the Cleveland Container Corporation, 601 West 26th Street, New York City. ASTM specified methods were used in that the concrete was poured in three equal layers and each layer was rodded twenty-five times throughout its depth. In conjunction with this, the sides of the wooden moulds and the cylinders were tapped with a maul in order to assure that the concrete would adhere to the sides of the moulds and voids would be eliminated. The excess concrete was struck off the moulds and the surface finished with a minimum of troweling.

The specimens were cast during the period from March 6, 1948 to April 3, 1948. The forty-five day samples were cast first, then the twenty-eight day samples and finally the

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 of the emulsion for wet cement. This method was deemed more
 desirable than placing the water since it more nearly simulated
 the probable field method. It was hoped, at this point, that
 due to this same affinity, the segregation of the aggregate, as
 noted in the mortar specimens, would not occur in the concrete.
 A further discussion of the possibilities of obtaining aggregate
 admixture is included in the conclusions to this thesis.

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 equal layers and each layer was rodded twenty-five times
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 of the wooden moulds and the cylinders were tapped with a
 mallet in order to insure that the concrete would adhere to the
 sides of the moulds and voids would be eliminated. The
 excess concrete was struck off the moulds and the surface
 finished with a minimum of trowelling.

The specimens were cast during the period from March
 6, 1943 to April 3, 1943. The forty-five day samples were
 cast first, then the twenty-eight day samples and finally the

seven day specimens. All specimens were removed from the forms within from twenty-four to forty-eight hours after pouring. Curing was accomplished by two methods: one was to completely cover the specimens with sand which was kept wet continuously and the other was by wrapping the specimens in wet burlap sacks, keeping them continuously wet also. All specimens were cured in this manner until the day of testing.

After the specified curing periods the specimens were transported from Scotia, New York to the Materials Testing Laboratory at Rensselaer Polytechnic Institute, Troy, New York. The concrete beams were tested for bending strength at the extreme fiber. Since all specimens were of exactly the same dimensions, the results are reported herein as simply the breaking load. A hand-balanced Olsen Testing Machine was used throughout the tests. Each beam was centered on two knife edges spaced at a distance of eighteen inches. A third knife edge was attached to the movable head of the machine and bore on the center of the beam, twelve inches from each end. Flat steel plates two inches by eight inches by one-quarter inch were inserted between each knife edge and the beam in order to prevent gouging of the beam by the knife edge. A linkage type strain gage with a linkage ratio of ten to one was connected between the movable head and the stationary supporting arm of the machine in order to give deflection readings of the beam centers. The clutching arrangement was set to give a head travel speed of 0.05 inches per minute.

seven day specimens. All specimens were removed from the forms within two days after pouring. Curing was accomplished by two methods: one was to completely cover the specimens with sand which was kept wet continuously, and the other was by wrapping the specimens in wet burlap sacks, keeping them continuously wet also. All specimens were cured in this manner until the day of testing.

After the specified curing periods the specimens were transported from Seattle, New York to the Materials Testing Laboratory at Massachusetts Polytechnic Institute, Troy, New York. The concrete beams were tested for bending strength at the extreme fibers. Since all specimens were of exactly the same dimensions, the results are reported herein as simply the breaking load. A hand-balanced Olsen Testing Machine was used throughout the tests. Each beam was centered on two knife edges spaced at a distance of eighteen inches. A third knife edge was attached to the movable head of the machine and bore on the center of the beam, twelve inches from each end. Five steel plates two inches by eight inches by one-quarter inch were inserted between each knife edge and the beam in order to prevent rounding of the beam by the knife edge. A linkage type strain gage with a linkage ratio of ten to one was connected between the movable head and the stationary supporting arm of the machine in order to give deflection readings of the beam centers. The dialing arrangement was set to give a beam travel speed of 0.05 inches per minute.

The test cylinders were tested on a standard Olsen Compression Testing Machine with the load applied at the rate of five thousand pounds per minute. Each cylinder was capped before testing with Plaster of Paris in order to give a smooth, level bearing surface on each end of the cylinders.

In view of the relatively recent knowledge of the importance of controlling the amount of air entrained in concrete mixtures, it was desired to determine what effect, if any, asphaltic emulsion would have on this property. The authors were fortunate in obtaining from the Research Laboratories of the Portland Cement Association one of their pressure measuring devices. A complete description of this apparatus with instructions for its use is contained in that organization's Bulletin 19 entitled "Procedure for Determining the Air Content of Freshly-Mixed Concrete by the Rolling and Pressure Methods" by Carl A. Menzel. This method is easier to apply and more accurate than the gravimetric method. As each batch of concrete, plain and with various percentages of emulsion was taken from the mixer, a test was conducted to determine the air content and the results are reported herein. Before use, the apparatus was calibrated for the area in which the tests were conducted.

The test cylinders were tested on a standard Diesel Compression Testing Machine with the load applied at the rate of five hundred pounds per minute. Each cylinder was capped before testing with flange of 1/2 inch in order to give a smooth, level bearing surface on each end of the cylinders.

In view of the relatively recent knowledge of the importance of controlling the amount of air contained in concrete mixtures, it was desired to determine what effect, if any, asphaltic emulsion would have on this property. The mixtures were prepared in accordance with the standard laboratory of the Portland Cement Association and of their concrete measuring device. A complete description of this apparatus with instructions for its use is contained in that organization's Bulletin 19 entitled "Procedures for Testing for the Air Content of Freshly-Mixed Concrete by the Boling and Pressure Methods" by Earl A. Rummel. This method is easier to apply and more accurate than the gravimetric method. As each batch of concrete, plain and with various percentages of emulsion was taken from the mixer, a test was conducted to determine the air content and the results are reported herein. Before use, the apparatus was calibrated for the values in which the tests were conducted.

SIEVE ANALYSIS OF COW BAY SAND

Used In Moulding Concrete Specimens

<u>Sieve Number</u>	<u>Weight Retained</u>	<u>Percent Retained</u>	<u>Percent Passing</u>
8	1.000	2.79	97.21
16	6.563	18.34	78.87
30	10.563	29.50	49.37
50	13.563	37.85	11.52
100	3.563	9.95	1.57
Passing	<u>.563</u>	<u>1.57</u>	
	35.815	100.00	

SLIVER ANALYSIS OF COW BAIT SAND Used in Moulding Concrete Specimens

Sliver Number	Weight Retained	Percent Retained	Percent Passing
8	1.000	2.72	97.28
15	0.253	13.34	86.66
30	10.263	28.20	71.80
50	12.263	37.22	62.78
100	2.263	9.92	90.08
Passing	1.263	1.27	98.73
	35.812	100.00	

PHASE III

FREEZE-THAW TEST OF CONCRETE SPECIMENS

With the knowledge that entraining an optimum percentage of air improves the durability of Portland cement concrete, it was felt that valuable data could be obtained from a freeze-thaw test. As far as the authors could determine no standard laboratory test of this nature was available at the time. A simple test was devised therefore, which consisted of subjecting three inch by six inch test cylinders to repeated freezing and thawing. The cylinders were placed in a refrigerator at a temperature of 5 °F for a period of twenty-four hours. They were then removed and placed in an oven at a temperature of 120 °F and left therein for the same period. After three such cycles, this test was interrupted and compression tests were conducted, the results of which are included elsewhere in this text. The tests indicated that the strengths of these samples compare with those of the normally cured specimens. There was no weight reduction at this time and no visible scaling or spalling. This was as expected. A much greater number of cycles would be needed for conclusive results.

PAGE III

PREFACE-TEST OF COMBUSTION SYSTEMS

With the knowledge that extending an optimum percentage of air improves the combustibility of fuel, it was felt that valuable data could be obtained from a freeze-thaw test. As far as the authors could determine no standard laboratory test of this nature was available at the time. A simple test was devised which consisted of subjecting glass inch of air inch cylinders to repeated freezing and thawing. The cylinders were placed in a refrigerator at a temperature of 5°F for a period of twenty-four hours. They were then removed and placed in an oven at a temperature of 120°F and left overnight for the same period. After three such cycles, this test was interrupted and compression tests were conducted, the results of which are included elsewhere in this test. The tests indicated that the strengths of these samples compared with those of the normally cured specimens. There was no weight reduction at this time and no visible swelling or spalling. This was as expected. A much greater number of cycles would be needed for conclusive results.

SEVEN DAY TENSILE STRENGTHS
OF STANDARD BRIQUET SPECIMENS

CAST February 17, 1948

TESTED February 24, 1948

<u>Type</u>	<u>Percent Asphalt</u>	<u>Sample Number</u>	<u>Tension P.S.I.</u>	<u>Average</u>
1:3 Mortar Mix Ottawa Sand	0	1	266	268
		2	264	
		3	275	
1:3 Mortar Mix Cow Bay Sand	0	1	403	403
		2	406	
		3	401	
	1	1	304	316
		2	369	
		3	274	
	2	1	315	335
		2	329	
		3	362	
	3	1	249	305
		2	340	
		3	325	
	4	1	298	300
		2	316	
		3	287	
	6	1	218	234
		2	295	
		3	190	
	8	1	185	198
		2	180	
		3	230	
	10	1	202	221
		2	238	
		3	224	
	12	1	181	129
		2	106	
		3	102	

STANDARD RAILWAY EQUIPMENT
SAVED BY TROOPERS

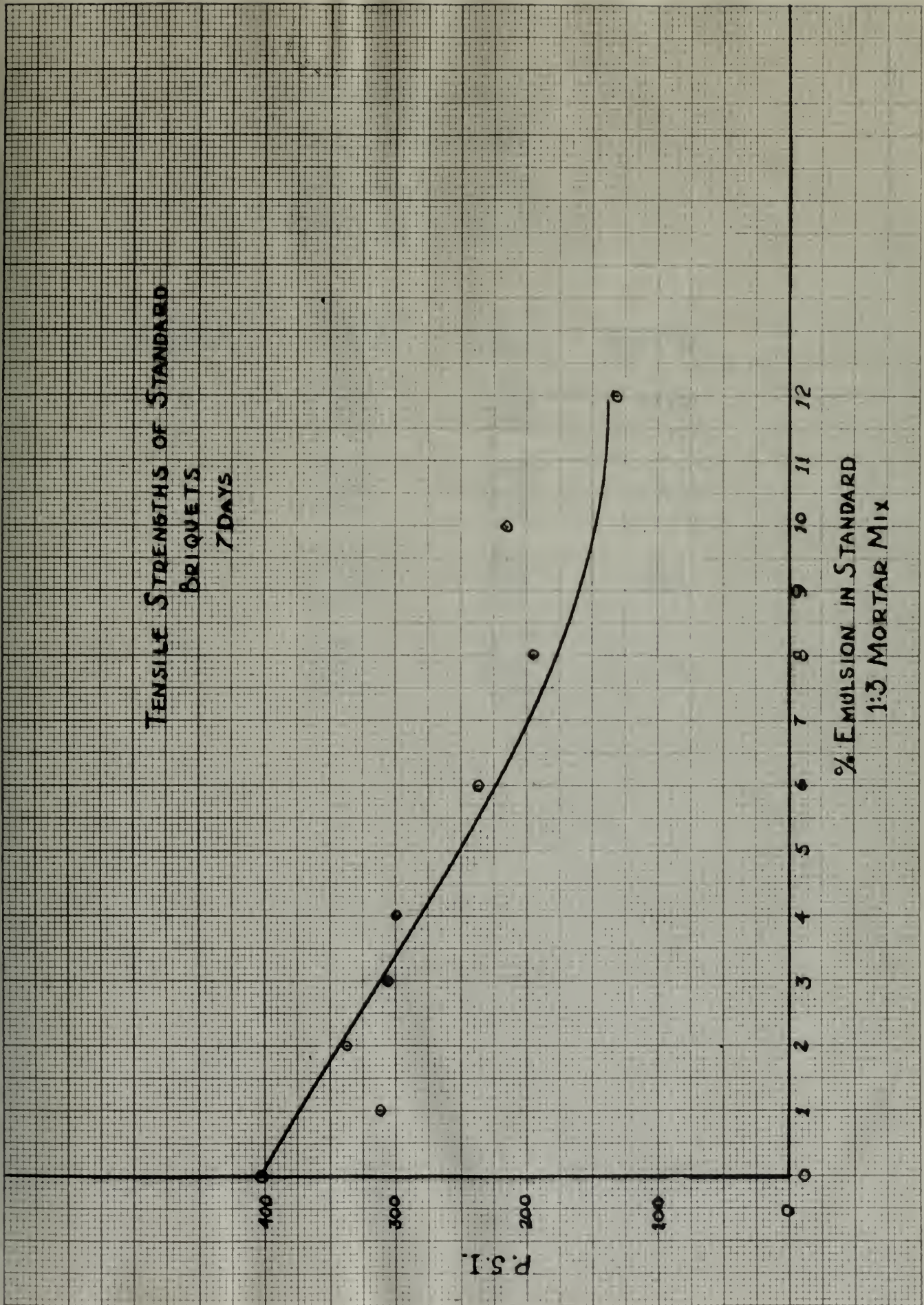
LAST REPORT IV, 1948

TESTED February 24, 1948

Type	Revolving Machinist	Sample Machinist	Yard Machinist	Aviation
1:1 Motor Mix Office Band	0	1	200	200
1:1 Motor Mix Cow Bay Band	0	2	200	200
		3	200	200
	1	2	200	200
	2	3	200	200
	3	4	200	200
	4	5	200	200
	5	6	200	200
	6	7	200	200
	7	8	200	200
	8	9	200	200
	9	10	200	200
	10	11	200	200
	11	12	200	200

TENSILE STRENGTHS OF STANDARD
BRIQUETS
7 DAYS

% EMULSION IN STANDARD
1:3 MORTAR MIX





COMPRESSIVE STRENGTH
of
SEVEN DAY CYLINDERS

CAST April 3, 1948

TESTED April 10, 1948

<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>P.S.I.</u>	<u>Average</u>
0	63600 lb	2255	2332
	69200	2450	
	64600	2290	
1	37600	1221	1391
	41300	1462	
	39000	1381	
2	36600	1297	1231
	36600	1297	
	31100	1100	
3	39000	1381	1387
	39000	1381	
	39500	1400	

COMPARATIVE STUDY
OF
STEAK AND CATTLE
TEST April 1, 1948
TESTED April 10, 1948

Percent of Sample	Breaking Load	P. I. I.	Analysis
0	8800 lb	1252	1252
	8800	1250	
	8800	1250	
1	8800	1251	1251
	8800	1251	
	8800	1251	
2	8800	1251	1251
	8800	1251	
	8800	1251	
3	8800	1251	1251
	8800	1251	
	8800	1251	

COMPRESSIVE STRENGTH
OF
7 DAY CYLINDERS

ULTIMATE STRENGTH PSI.

4000

3000

2000

1000

0

1

2

3

% ASPHALT

0

1

2

3

DEFLECTION AND BREAKING LOAD

SEVEN DAY BEAMS

CAST April 3, 1948

TESTED April 10, 1948

<u>Percent of Asphalt</u>	<u>Deflection</u>	<u>Breaking Load</u>	<u>Average</u>
0	.055 In.	3600	4423
	.085	4870	
	.060	4800	
1	.065	3350	3310
	.055	3350	
	.055	3230	
2	.080	2750	3260
	.070	3360	
	.090	3670	
3	.055	3075	3362
	.070	3440	
	.060	3570	

DEFLECTION AND BREAKING LOAD

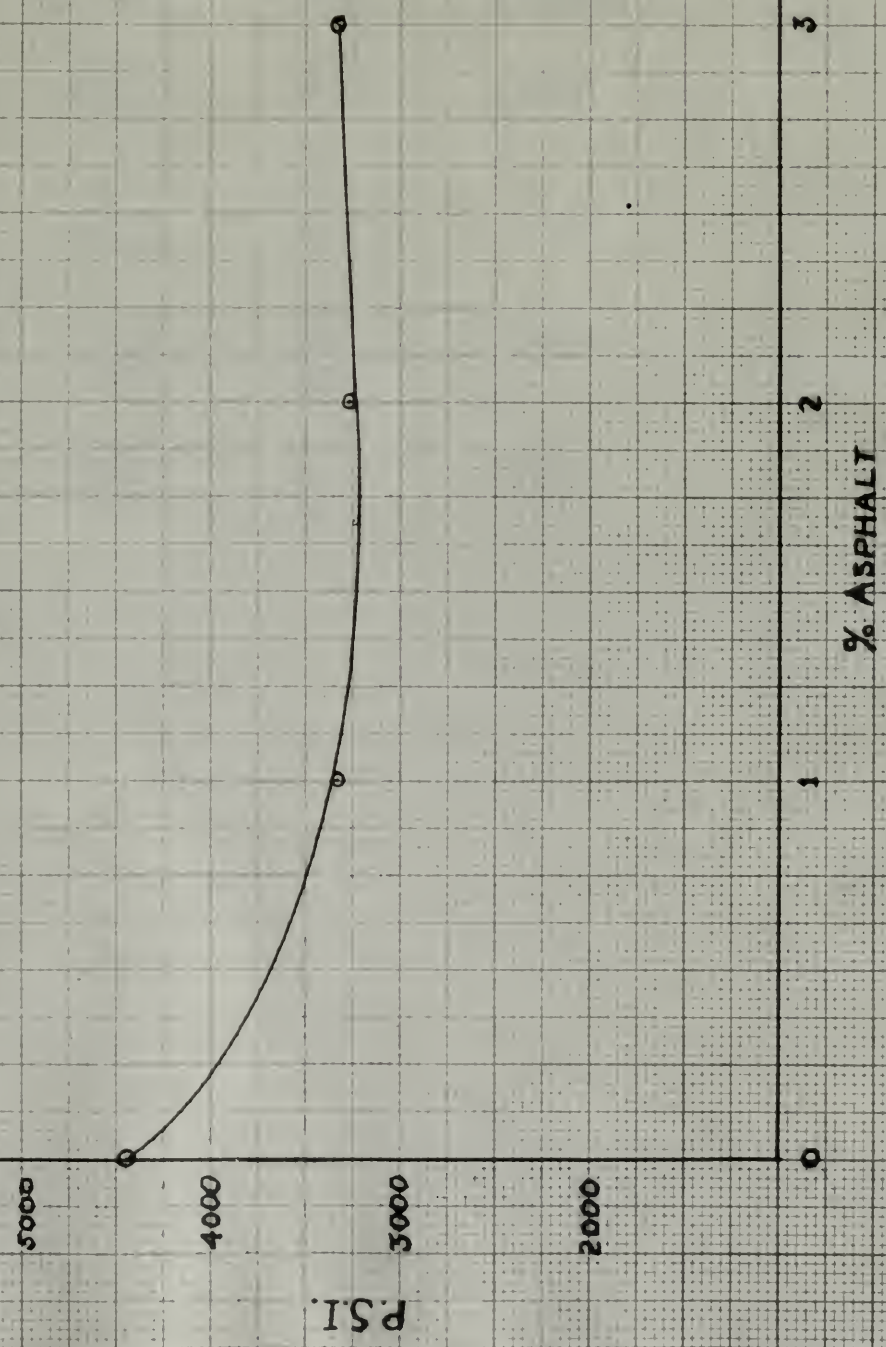
SEVEN DAY BEAMS

CAST April 3, 1948

TESTED April 10, 1948

Percent of Span	Deflection	Breaking Load	Average
0	.055 in. .082 .060	3600 4870 4800	4423
1	.065 .075 .072	3350 3200 3200	3210
2	.080 .072 .060	4750 3300 3070	3560
3	.095 .070 .060	3075 3440 3270	3262

BREAKING LOAD
7 DAY BEAMS



COMPRESSIVE STRENGTH
of
TWENTY-EIGHT DAY CYLINDERS

CAST March 12-13, 1948
TESTED April 9-10, 1948

<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>P.S.I.</u>	<u>Average</u>
0	98400	3480	3525
	100500	3560	
	99800	3535	
1	48400	1750	1726
	48000	1700	
	48900	1730	
2	72700	2575	2393
	66600	2360	
	63500	2245	
3	52900	1870	1773
	50000	1770	
	47700	1690	

COMPRESSIVE STRENGTH
of
TWENTY-EIGHT DAY CILINDERS

CAST March 12-13, 1948
TESTED April 9-10, 1948

<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>P.S.I.</u>	<u>Average</u>
0	98400 100500 99800	3180 3200 3232	3222
1	48400 48000 48200	1730 1708 1730	1726
2	72700 66600 63200	2272 2208 2242	2293
3	25200 20000 17700	1170 1170 1190	1173

COMPRESSIVE STRENGTH
OF
28 DAY CYLINDERS

4000

3000

2000

1000

PSI

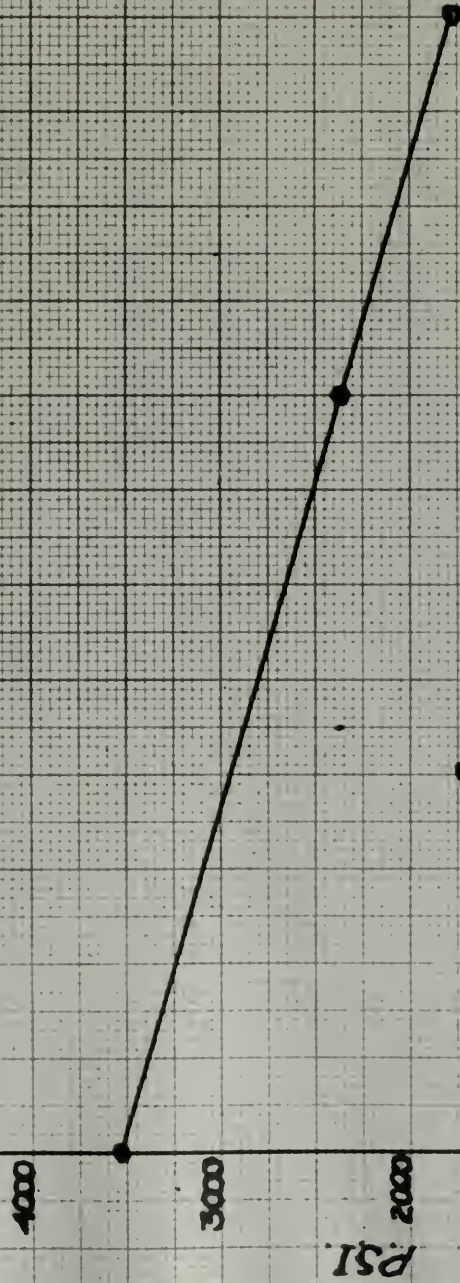
0

1

2

3

% OF ASPHALT



DEFLECTION AND BREAKING LOAD
 TWENTY-EIGHT DAY BEAMS

CAST March 12-13, 1948
 TESTED April 9-10, 1948

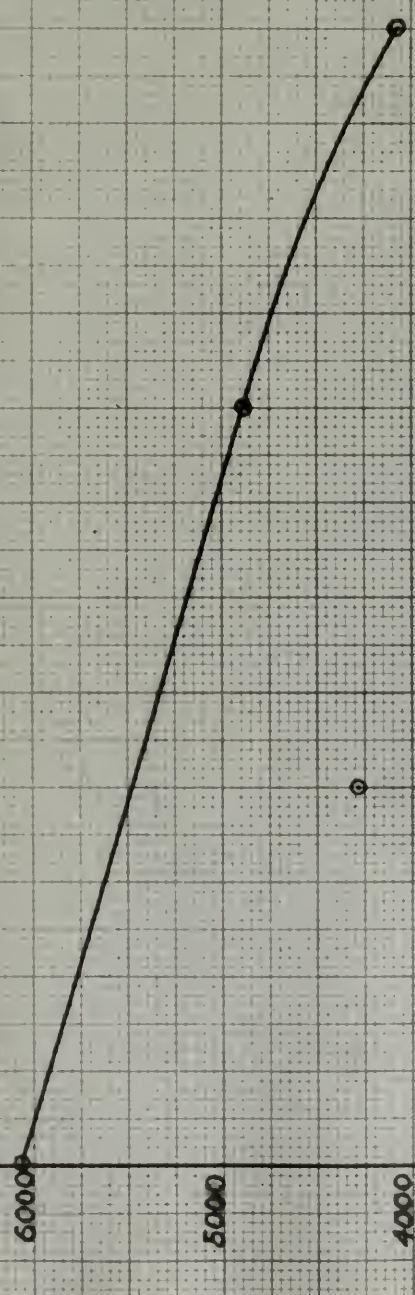
<u>Percent of Asphalt</u>	<u>Deflection</u>	<u>Breaking Load</u>	<u>Average</u>
0	.07 In.	6070 Lb.	6074
	.07	7150	
	.07	6078	
1	.08	4170	4270
	.05	5100	
	.06	4370	
2	.08	5050	4876
	.06	4960	
	.06	4620	
3	.06	4078	4079
	.06	4080	
	.05	4655	

DEFLECTION AND BREAKING LOAD TWENTY-EIGHT DAY BEAMS

TESTED April 9-10, 1948
CAST March 12-13, 1948

<u>Percent of Support</u>	<u>Deflection</u>	<u>Breaking Load</u>	<u>Average</u>
0	.07 in. .07 .07	6070 lb. 7150 6078	6074
1	.08 .07 .08	4770 5100 4770	4770
2	.08 .08 .08	5050 4950 4950	4876
3	.08 .08 .05	4078 4080 4622	4079

BREAKING LOAD
28 DAY BEAMS



3

2

1

0

% OF ASPHALT

POUNDS

COMPRESSIVE STRENGTH
of
FORTY-FIVE DAY CYLINDERS

CAST March 5-6-7, 1948

TESTED April 19-20-21, 1948

<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>P.S.I.</u>	<u>Average</u>
0	117000	4150	3687
	102400	3630	
	92750	3280	
1	103600	3665	3345
	83500	2960	
	96350	3410	
2	66700	2365	2363
	63600	2255	
	69700	2470	
3	51400	1820	1910
	53300	1890	
	57000	2020	

COMPRESSIVE STRENGTH
of
FORTY-FIVE DAY CEMENTS
CASE March 2-6-7, 1912
TESTED April 19-20-21, 1912

Percent of Asphalt	Breaking Load	P.S.I.	Average
0	117000 102400 92750	4750 3630 3380	3487
1	109600 93200 86750	3665 2960 2470	3242
2	86700 69600 66700	2965 2222 2470	2362
3	51400 23700 20000	1820 1360 2020	1610

COMPRESSIVE STRENGTH
OF
45 DAY CYLINDERS

ULTIMATE STRENGTH PSI

% OF ASPHALT

0

1

2

3

4000

3000

2000

1000

DEFLECTION AND BREAKING LOAD
FORTY-FIVE DAY BEAMS

CAST March 5-6-7, 1948

TESTED April 19-20-21, 1948

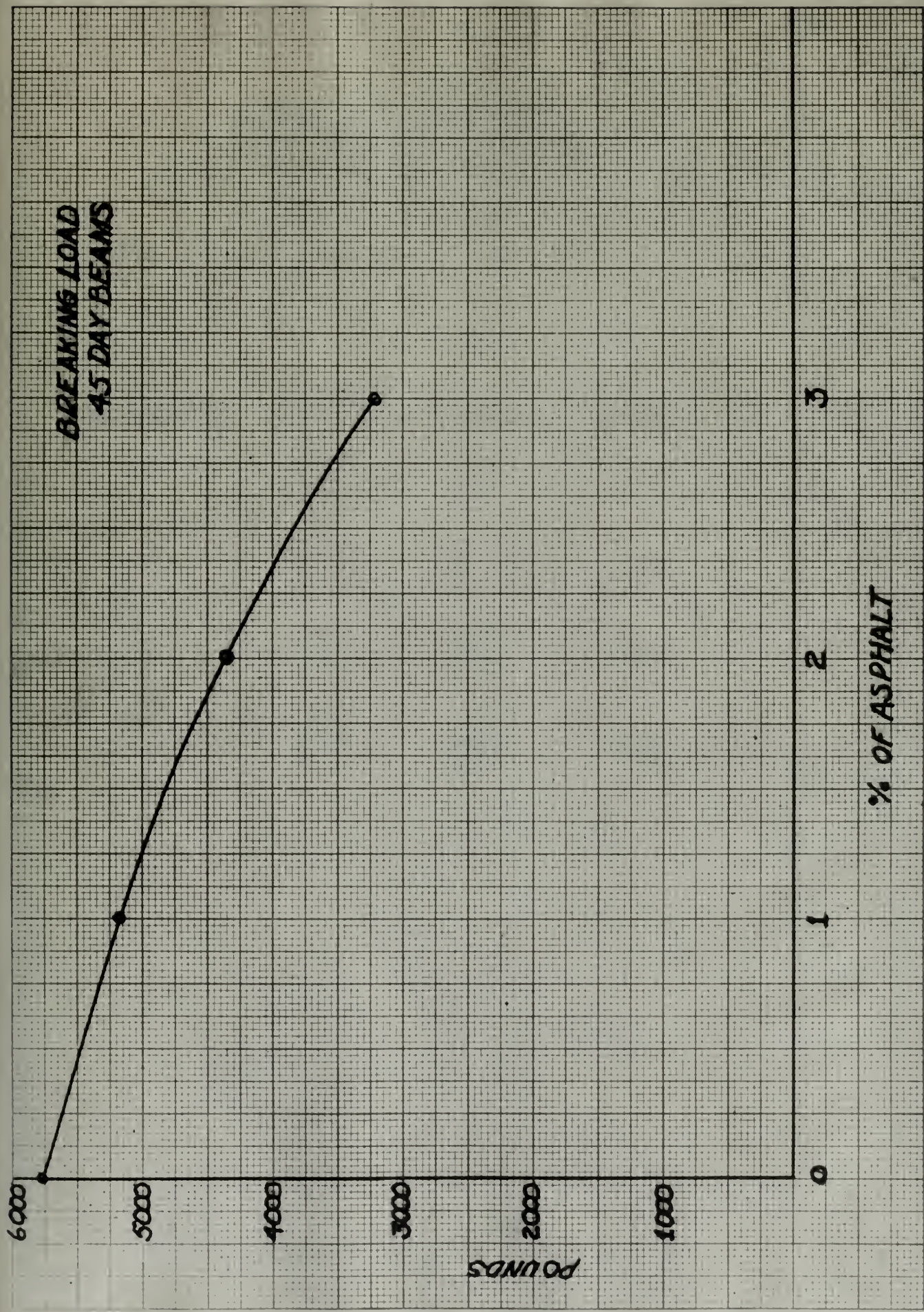
<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>Deflection</u>	<u>Average</u>
0	0.100	5170	5777
	0.110	5560	
	0.080	6600	
1	0.072	5030	5158
	0.070	5285	
	0.065	6330	
2	0.055	4000	4350
	0.065	4700	
	0.065	4350	
3	0.060	3240	3205
	0.060	4110	
	0.060	3170	

DEFLECTION AND BREAKING LOAD FOUR-FIVE DAY BEAMS

TESTED MARCH 5-6-7, 1948

TESTED APRIL 19-20-21, 1948

Percent of Asphalt	Breaking Load	Deflection	Average
0	0.100 0.110 0.080	2170 2260 6600	2777
1	0.072 0.070 0.062	2030 2282 6330	2122
2	0.052 0.052 0.052	4000 4700 4320	4320
3	0.060 0.060 0.060	3240 4110 3170	3202



COMPRESSIVE STRENGTH OF
THIRTY-FIVE DAY CYLINDERS
AFTER THREE TWENTY-FOUR HOUR
FREEZE-THAW CYCLES

CAST April 3, 1948

TESTED May 7, 1948

<u>Percent of Asphalt</u>	<u>Breaking Load</u>	<u>P.S.I.</u>	<u>Average</u>
0	22700	3215	3607
	26600	3770	
	27100	3836	
1	15300	2165	2247
	16400	2322	
	15800	2224	
2	15300	2165	2200
	15500	2195	
	15800	2240	
3	9000	1273	1675
	11900	1686	
	14600	2068	

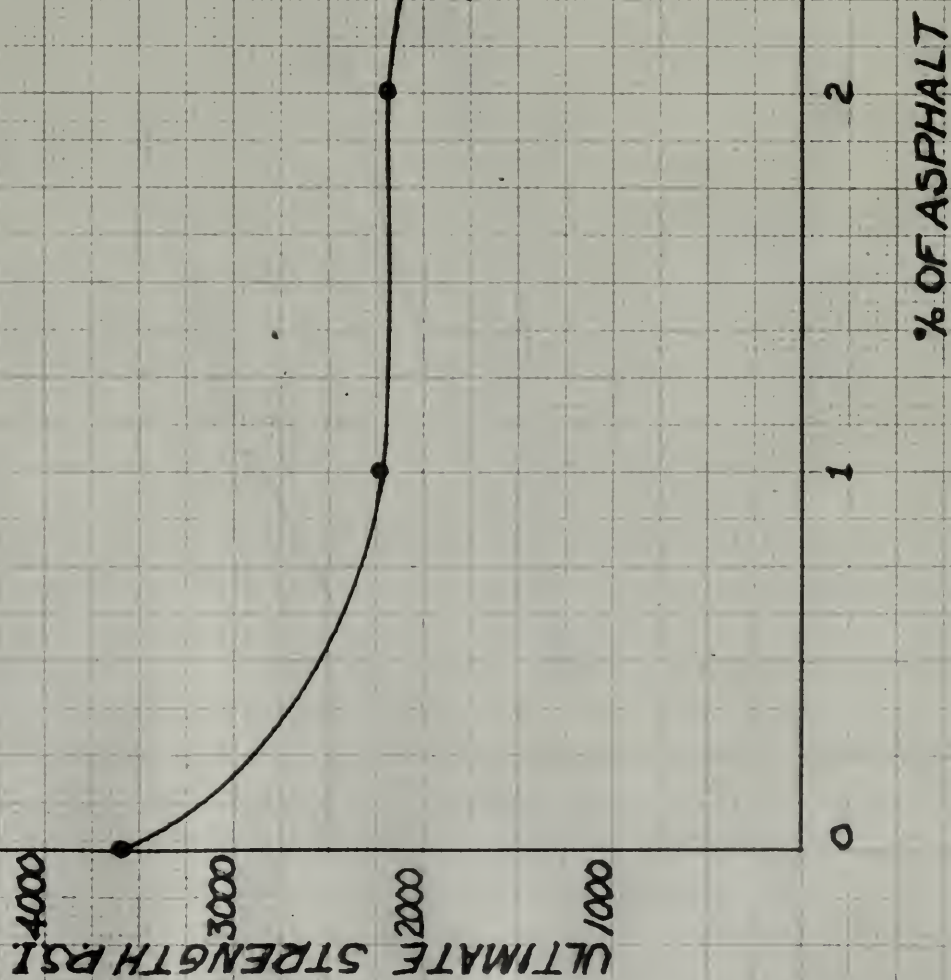
COMPRESSIVE STRENGTH OF
THIRTY-FIVE DAY CEMENT
AFTER THREE TWENTY-FOUR HOUR
WETTED-TWENTY CYCLES

TESTED April 3, 1948

TESTED May 7, 1948

<u>Percent</u> <u>of Strength</u>	<u>Breaking</u> <u>Load</u>	<u>P.C.I.</u>	<u>Average</u>
0	2100 2200 2300	215 220 230	360
1	1500 1600 1700	225 235 245	245
2	1500 1600 1700	215 225 235	200
3	1400 1500 1600	125 135 145	105

COMPRESSIVE TEST
OF 35 DAY CYLINDERS
AFTER 3-24 HOUR FREEZE
THAW CYCLES



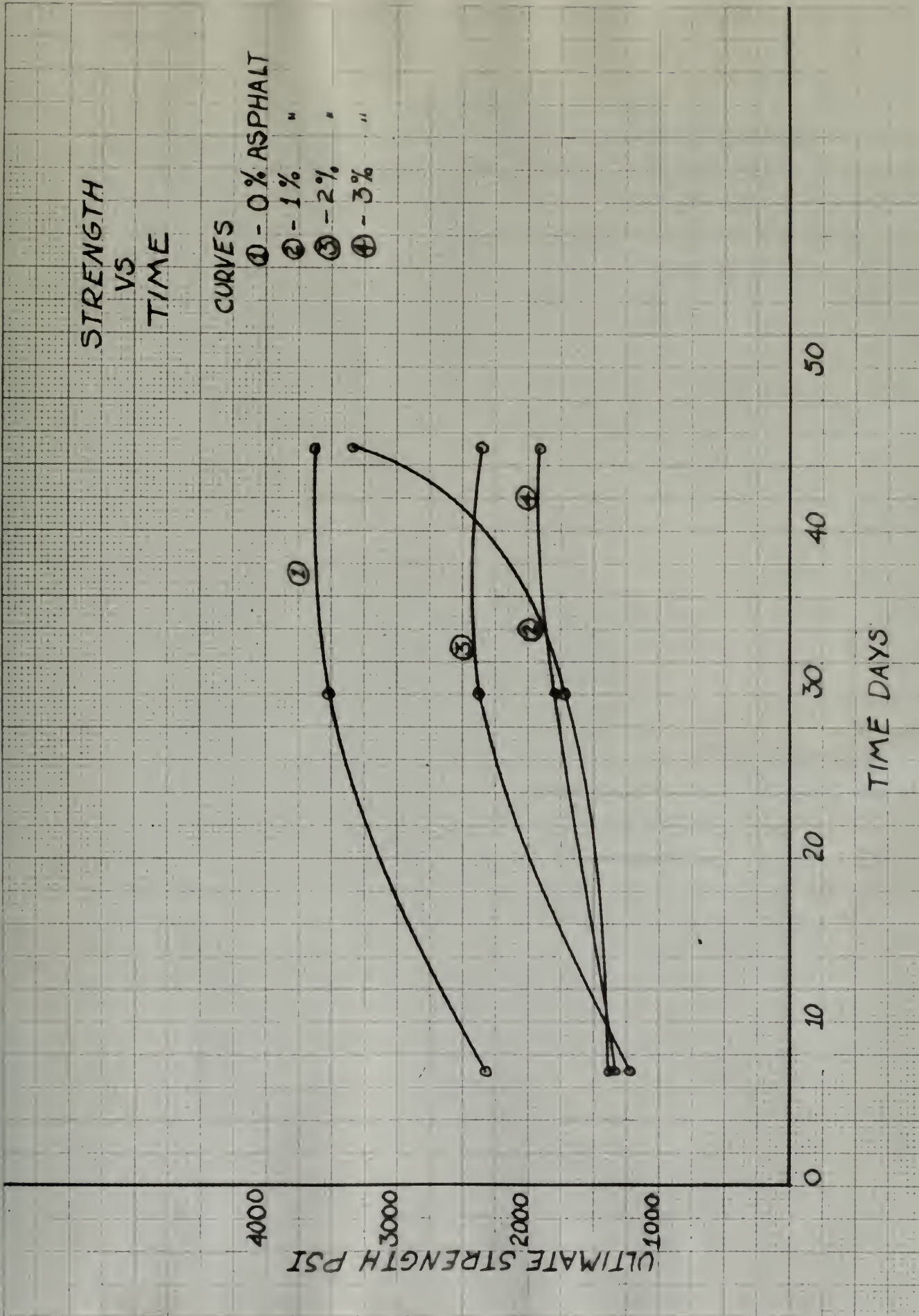
STRENGTH VS TIME

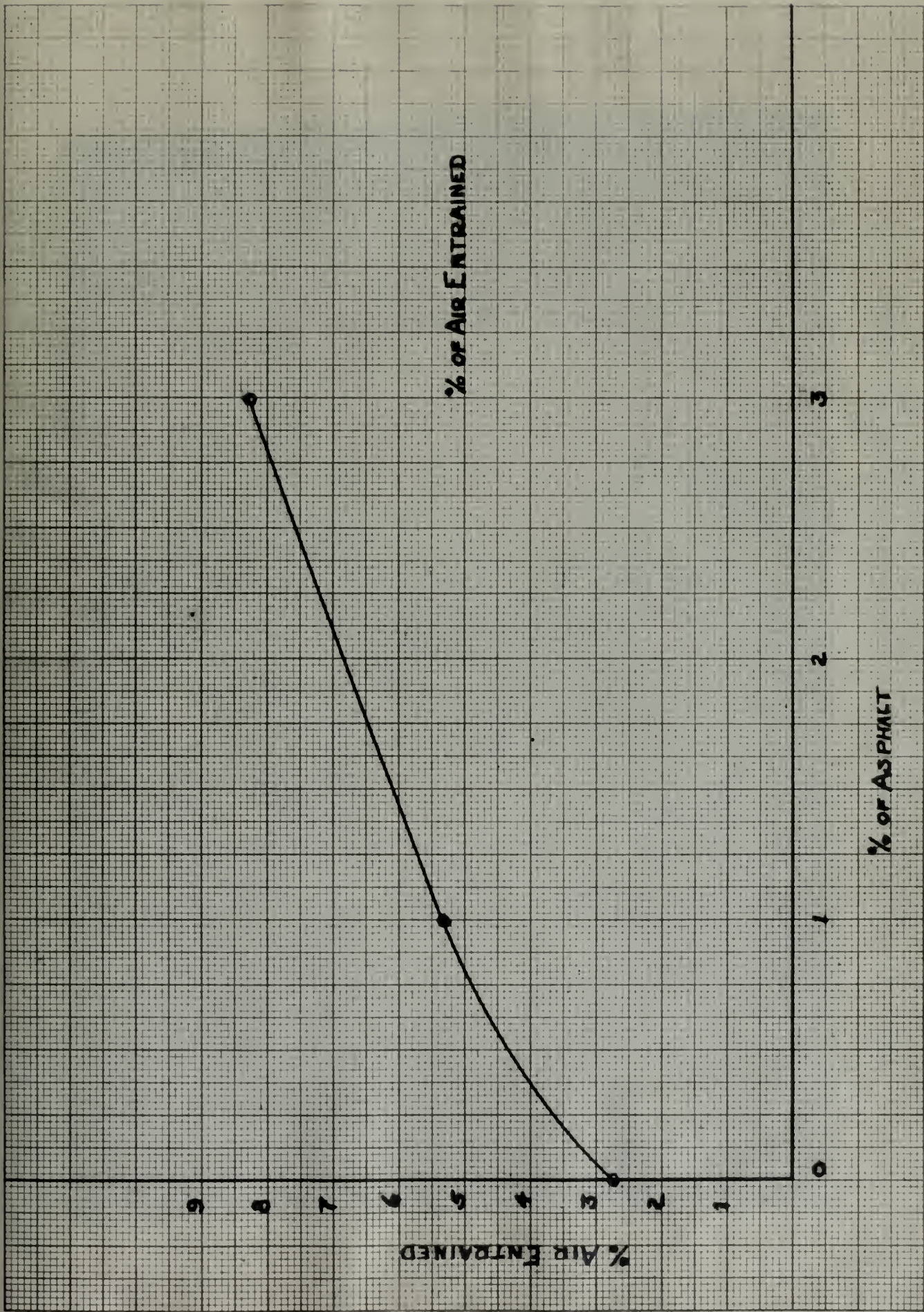
CURVES

- ① - 0% ASPHALT
- ② - 1% "
- ③ - 2% "
- ④ - 3% "

ULTIMATE STRENGTH PSI

TIME DAYS





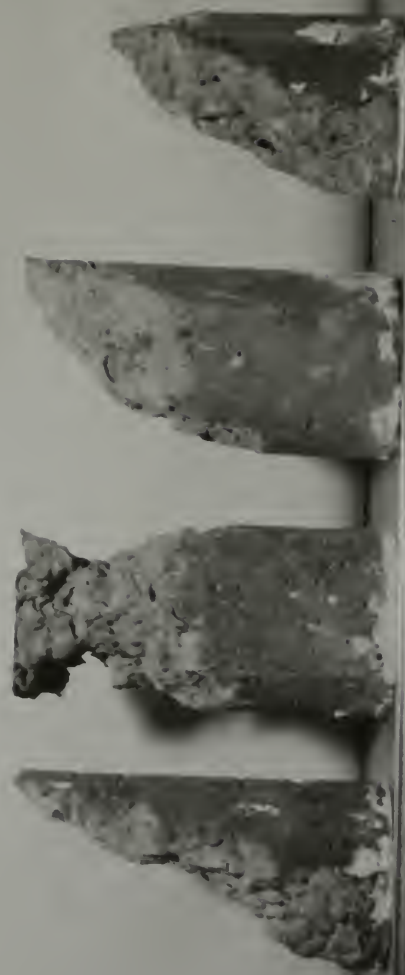


Cross Sectional View of Concrete Beams Containing Aggregate

Dark areas are asphalt inclusions



Typical Fracture of Concrete Beams



Typical Fractures of Concrete Cylinders
Left to right: 0, 1, 2, 3 % emulsion

CONCLUSIONS

At this stage of the investigation it must be concluded that the results are essentially negative.

The authors, however, feel that the subject warrants further study. While the results shown indicate adverse effects on strength of concrete containing asphalt emulsion, a small reduction of strength can be tolerated if other desirable properties are improved. In general no marked improvement of properties with the exception of air-entrainment was observed. It must be realized, however, that necessarily only one type of emulsion was used; that short-time tests were conducted; that arbitrary methods of mixing were used; and that a particular cement, aggregate, and sand were used. Obviously then, there is much further research to be carried on before the idea of using an asphaltic emulsion as an admixture in concrete should be abandoned.

Further consideration should be given to the selection of the particular asphaltic emulsion best suited, as the particle size in different emulsions ranges from very fine to very coarse, or from about one micron to ten microns.

"An emulsion being essentially a disperse system, its state of dispersion is necessarily one of its most important characteristics. Two aspects of the degree of dispersion are important: (1) The mean absolute size of the particles, and (2) The range size of the particles and their distribution throughout the range size".

CONCLUSIONS

As this study of the investigation is not yet concluded that the results are essentially negative. The authors, however, feel that the subject warrants further study. While the results shown indicate adverse effects on strength of concrete containing asphalt emulsion, a small reduction of strength can be tolerated if other desirable properties are improved. In general no marked improvement of properties with the exception of air-entrainment was observed. It must be realized, however, that necessarily only one type of emulsion was used; that short-time tests were conducted; that arbitrary methods of mixing were used; and that a particular cement, aggregate, and sand were used. Obviously then, there is much further research to be carried on before the idea of using an asphaltic emulsion as an admixture in concrete should be abandoned.

Further consideration should be given to the selection of the particular asphaltic emulsion best suited, as the particle size in different emulsions ranges from very fine to very coarse, or from about one micron to ten microns. An emulsion being essentially a disperse system, its state of dispersion is necessarily one of its most important characteristics. Two aspects of the degree of dispersion are important: (1) The mean absolute size of the particles, and (2) The range size of the particles and their distribution throughout the range size.

Many valuable properties could be investigated by tests requiring much longer periods of time. Among these can be included the control of temperature stresses due to the expansion and contraction of concrete through the reaction between cement and aggregate (ref. Paper 2129, ASCE Transactions, Vol. 107, p. 54, 1942).

In practice, the advantages of air entrainment upon the durability of concrete have been exhibited only after years of being subjected to the freezing and thawing forces of nature. The fact that the amount of air entrained in concrete mixtures can be controlled by the addition of definite amounts of asphaltic emulsion indicates that this material will at least accomplish the same result as other commercial products used for this purpose. To obtain maximum information from the proposed freeze-thaw test, a far greater number of cycles should be completed before results can be considered conclusive.

Overcoming the macroscopic segregation of the asphaltic material appears to be the major problem before the full capabilities of the admixture can be realized. Many methods, applicable to laboratory use, become impractical in the field. It is suggested, however, that a better distribution might be obtained by spraying it over the wet mix and then continuing mixing until the asphalt is uniformly distributed throughout the plastic mass.

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